HIGH-EFFICIENCY TURBULATORS FOR HIGH-STAGE GENERATOR OF ABSORPTION CHILLER/HEATER

BACKGROUND OF THE INVENTION

[0001] This invention relates to turbulators to be utilized in an environment wherein reducing the pressure drop across the turbulator is important. One particularly preferred application is in a high-stage generator for an absorption chiller/heater wherein the heat source is the exhaust of an engine such as a micro-turbine.

[0002] Refrigerant absorption cycles have been used for decades to provide a cooled or heated water source for environmental temperature control in buildings. As is known, an absorber and an evaporator in a refrigerant absorption cycle selectively receive a concentrated absorption fluid, such as a LiBr solution, and a separate refrigerant (often water), respectively. The absorption fluid is selectively dropped onto separate tube sets in the absorber and absorbs the refrigerant vapor generated from the evaporator. A dilute solution, containing both the absorption fluid and the refrigerant is then returned to a generator for generating a heated, concentrated absorption fluid. In the generator, a driving heat source drives the refrigerant vapor out of the mixed fluid. From the generator, the absorption fluid and removed refrigerant vapor are separately returned to the absorber and the evaporator, respectively.

[0003] The above is an over-simplification of a complex system. However, for purposes of this application, the detail of the system may be as known. Further, while the above-described system provides chilled water, absorption cycles are also utilized to provide heated water for heating of a building. This invention would extend to such systems. For purposes of this application, an absorption chiller and an absorption heater are to be defined

generically in the claims as an "absorption solution/refrigerant system." A worker of ordinary skill in the art would recognize the parallel absorption heater systems and how such systems differ from the disclosed chiller system.

[0004] These systems deliver the heated exhaust air to a number of channels known as "smoke tubes." The smoke tubes are positioned between a number of flow passages that communicate the absorption mixture around the smoke tubes to transfer heat to the absorption fluid.

[0005] In the prior art, the turbulators have blades secured to an elongated member. The blades typically have rectangular flanges at a normal angle relative to a central web. The blades provide good heat transfer characteristics. However, in the prior art, the source of heat has been a dedicated source of heat. At times, it may be useful to utilize a source of exhaust heat generated from another separate system to provide the heated fluid. As an example, it may be desirable to utilize the exhaust of a micro-turbine to provide the heat source. The prior art rectangular flanges, in both their shape and arrangement, create a downstream wake region, which increases the pressure drop across the smoke tube. This increase in pressure drop can provide efficiency concerns back upstream to the prime mover (i.e., the micro-turbine). This is undesirable.

SUMMARY OF THE INVENTION

[0006] In a disclosed embodiment of this invention, turbulators are proposed to minimize the pressure drop across the smoke tube. Preferably, the turbulator designs are constructed to provide adequate heat transfer characteristics while still minimizing the pressure drop.

[0007] In a first embodiment, the turbulator has a central web secured to an elongate connecting member. The central web has flanges extending at a non-normal angle. These flanges minimize wake beyond the turbulator blades, and thus reduce the pressure drop. Further, inward of the outermost flanges are a series of cutout members, and which extend in both directions from the central web. The turbulator blades are placed on alternating sides of the connecting member. The overall arrangement is such that the pressure drop along the turbulator is reduced. Thus, a greater number of blades can be mounted on the turbulator without increasing, or perhaps reducing, the pressure drop when compared to known turbulators. This will then provide better heat transfer characteristics.

[0008] In a second embodiment, the flanges may extend at a normal angle relative to the central web, however, they are non-rectangular, and may be in the shape of a triangle. In this manner, the same benefits of reducing wake and thus pressure drop are achieved.

[0009] These and other features of the present invention can be best understood from the following specification and drawings, the following of which is a brief description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Figure 1 is a schematic view of an absorption heater/chiller.

[0011] Figure 2A shows a known smoke tube arrangement.

[0012] Figure 2B shows a detail of the Figure 2A arrangement.

[0013] Figure 2C is the side view of the Figure 2B arrangement.

[0014] Figure 3 shows a first embodiment turbulator for use in the Figure 2A smoke tube.

[0015] Figure 4 is a side view of a blade in the Figure 3 turbulator.

[0016] Figure 5 is a top view of the Figure 3 blade.

[0017] Figure 6 shows a second embodiment blade.

[0018] Figure 7 is a side view of the Figure 6 blade.

[0019] Figure 8 is a view of the assembled second embodiment blade.

[0020] Figure 9 shows a graph of a friction factor, and the number of blades for the prior art and the two inventive designs.

[0021] Figure 10 shows the heat transfer coefficient plotted against the number of blades for the first embodiment and the prior art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] Figure 1 shows an absorption chiller/heater or an "absorption solution/refrigerant system." In particular high-stage generator 20 receives a source of heat 22. In a preferred embodiment, heat source 22 may be a micro-turbine or some other engine, supplying exhaust air to an inlet duct 24. Inlet duct 24 communicates the heated air to an outlet 26, and from the outlet 26 downstream such as to atmosphere 28.

[0023] The absorption chiller/heater incorporates an absorber 30 in which heat is exchanged between an absorption solution and a medium to be heated or cooled. As known, the absorption solution passes through an inlet line 32, communicating to a smoke tube assembly 36. From the smoke tube assembly 36, the absorption solution, and a boiled off refrigerant leave through an exit line 34. The fluid flow details are as known, as shown schematically.

[0024] As shown in Figure 2A, the smoke tube arrangement includes a plurality of channels 38 or smoke tubes, each including a turbulator 140. The exhaust flow from the

inlet 24 passes over these turbulators 140. The goal of the turbulators is to create turbulence, and thus increase the heat transfer coefficient of the exhaust air. Though not shown in this figure, it is known in this art that the absorption solution passes through channels arranged around the channels 38, such that heat is transferred from the channels 38 to the absorption solution.

[0025] Figure 2B shows a prior art turbulator. As can be appreciated, the prior art turbulator 140 incorporates blades 143 with flanges 146, 148, 150 extending at a perpendicular or normal angle to a central web 144 blades.

[0026] The blades 143 are secured to a central elongate connecting member 142. A hook member 141 secures the turbulator 140 within the channel 38, as known. The innermost flanges 148 and 150 extend in opposed directions relative to the central web 150, and are normal and rectangular. The outermost flanges 146 are generally rectangular, but have a notch 147 at an outermost edge. As can be seen, alternating blades 143 are mounted on an opposed side of the elongate connecting member 142. While the turbulator 140 as shown in Figures 2A-2C does provide good heat transfer characteristics, it also creates wake regions downstream of the blades, and thus an undesirably large pressure drop. Figure 2C shows the arrangement of the flanges 146, 148 and central web 144 on a blade 143.

[0027] Figure 3 shows an inventive turbulator 40. Turbulator 40 includes a central connecting member 42. A hook 46 assists in securing the turbulator within the channel 38. A blade 47 includes a central web 48. The central web extends to the laterally outermost edges having a first flange 50 having an angled edge 52, and a top portion 54. An inner edge 55 forms the final shape of the flange 50. Further, flanges 56 extend from central web 55, and are non-rectangular. As shown, a rectangular cutout 58 is formed in the flanges

56. Yet a third flange 60 also has a rectangular cutout 58. The third flange 60 is generally aligned over the connecting member 42 when the blade 48 is welded to the connecting member 42. As can be appreciated in this figure, alternating blades 48 and 49 are positioned upon opposed sides of the connecting member 42 in this embodiment.

[0028] As shown in Figure 4 (and also Figure 3), the flanges 60, 56 and 50 all extend at a non-normal angle relative to the central web 55. The angle in one embodiment is between 30 and 45° relative to the plane of the central web.

[0029] Further detail of the blade 48 can be appreciated from Figure 5.

[0030] Figure 6 shows another turbulator embodiment 70. Turbulator 70 has a central web 72, and outermost flanges 74. As can be appreciated, outermost flanges 74 are generally non-rectangular. The exact shape of the flanges 74, 76 and 78 are triangular, however, it should be appreciated that other non-rectangular shapes, and in particular those that have notches or cutaway portions at each lateral side of the flanges provide the benefit of reducing wake, and thus reducing pressure drop. Inner flanges 76 extend from the central web 72 in a direction opposed to the direction from which the flange 74 extends. As can be appreciated from this figure, the cross-sectional area of the flanges 76 is smaller than the cross-sectional area of flange 74, although there are preferably two of the flanges 76 on each lateral side. Central flanges 78 are also triangular and extend in the first direction from the central web. As shown in Figure 7, central web 72 receives the flanges 74 and 76 at a normal orientation.

[0031] As shown in Figure 8, the blades are attached to a central connecting member 80 in a manner similar to the first embodiment.

[0032] Figure 9 graphically shows some results of the prior art (Figure 2A), the first embodiment (Figure 3), and the second embodiment (Figure 8). As can be seen, the friction factor is greatly reduced in the inventive turbulators when compared to the prior art. This in turn results in a decrease in pressure drop.

[0033] Figure 10 shows that the prior art may well have the higher heat transfer coefficient than the first embodiment 40 (Figure 3). However, due to the friction factor decrease as shown in Figure 9, a greater number of blades can be utilized with the inventive design than was the case with the prior art. As such, adequate heat transfer can still be achieved.

[0034] Although triangular flanges are shown in Figure 6, and rectangular cutouts from an otherwise rectangular shape in Figure 5, other non-rectangular shapes may come within the scope of this invention.

[0035] Although a preferred embodiment of this invention has been disclosed, a worker of ordinary skill in this art would recognize that certain modifications would come within the scope of this invention. For that reason, the following claims should be studied to determine the true scope and content of this invention.